

Most generally, it is concluded that, at least in the area studied, the whole-sulfide associations observed in the spinel-lherzolite xenoliths, crystallized directly or were differentiated from a primary homogeneous liquid which individualized at high temperatures

($> 1200^{\circ}\text{C}$) and is characterized by a relatively high Ni content. Preliminary results show that the same hypothesis can be applied to explain the origin of the sulfide phases in the spinel-lherzolites of the ultramafic bodies from Ariege (French Pyrenees).

H11
SUBSOLIDUS PHASE RELATIONS BETWEEN COEXISTING GARNET AND PYROXENES AT 50 TO 100 kbar IN THE SYSTEM $\text{CaO-MgO-AL}_2\text{O}_3\text{-SiO}_2$

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Extensive experimental studies simulating chemical compositions of coexisting garnet, orthopyroxene and clinopyroxene of kimberlite xenoliths have been made in the system $\text{CaO-MgO-AL}_2\text{O}_3\text{-SiO}_2$ (e.g. Boyd, 1970; Akella, 1976; Parkins & Newton, 1980). Most of these studies, however, are in the pressure range below 40 kbar, because of the limitation with the piston-cylinder apparatus. Akaogi & Akimoto (1977, 1979) carried out a series of high pressure experiments with a multi anvil type high-pressure apparatus and found that the composition of garnet coexisting with pyroxenes becomes nonstoichiometric (pyroxene-garnet solid solution) above about 50 kbar, and the amount of pyroxene components dissolved in the garnet increases drastically at higher pressures. In order to clarify the thermodynamic nature of the garnet solid solution in equilibrium with two pyroxenes in the pressure range 50 to 100 kbar and formulate geothermometer and geobarometer for kimberlite xenoliths, we have started a series of high pressure experiments. A preliminary result of the experiments is given in this report.

All the experiments were made with a uniaxial split-sphere type multi-anvil apparatus of the Institute for Thermal Spring Research (Ito & Yamada, 1982), using graphite heater and pyrophyllite pressure media. In order to improve the thermal gradient across the experimental charge, a graphite heater with 5° taper (2.2 mm average I.D., 3 mm O.D., and 11 mm length) was designed (Takahashi et al., 1982). Experimental run temperatures are believed to be within 20°C to the measurements by the Pt/Pt-Rh thermocouples with the aid of the tapered heater. Two types of starting materials were employed; 1) EWC, which is a glass of enstatite 72.5 mol %, wollastonite 20.0%, corundum 7.5%; and 2) EDP, which is a mixture of synthetic enstatite, diopside and pyrope crystals equivalent to EWC in bulk chemical composition. Both the charges were encased in a Pt-tube (0.9 mm O.D., 2 to 3 mm length) and 0.1 to 3.0 wt % of H_2O was added prior to welding the Pt. Experimental run products were sectioned parallel to the length of the furnace assembly and the thin sections were examined with an electron microprobe X-ray analyzer.

Reversal experiments have been made at 1400°C and 75 kbar (Fig.1) and it was found that pyroxenes crystallized from both the starting materials give identical chemical compositions. Garnets started from the crystalline mixture (EDP) are chemically zoned but the rim compositions are very close to those from the hydrous glass (EWC). The compositions of coexisting garnet, orthopyroxene and clinopyroxene crystallized from EWC at other P/T conditions are shown in Fig.2.

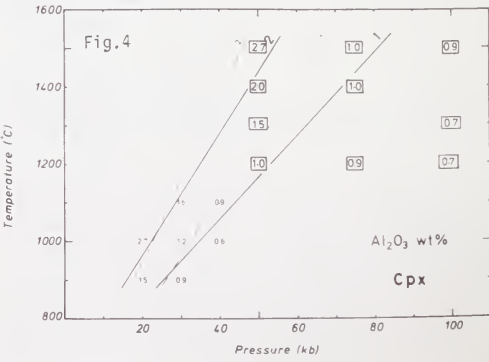
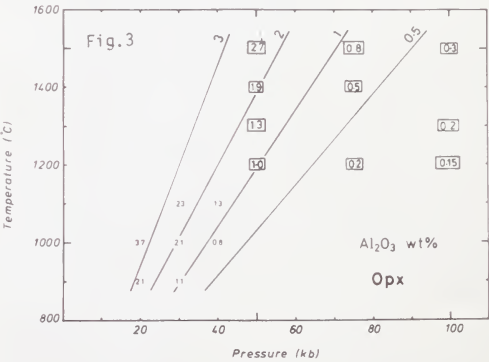
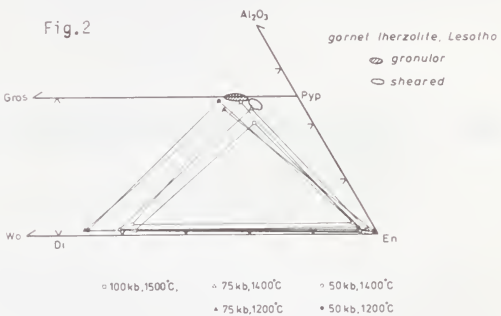
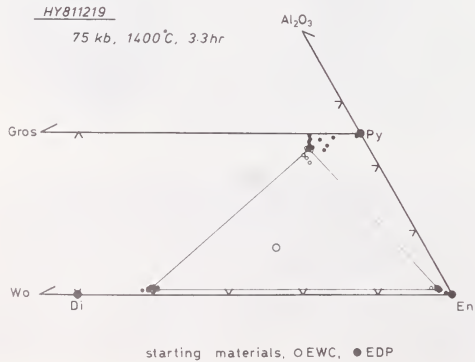
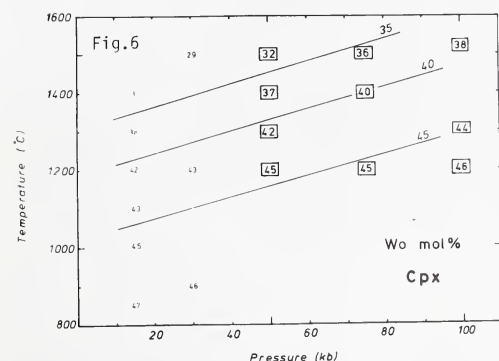
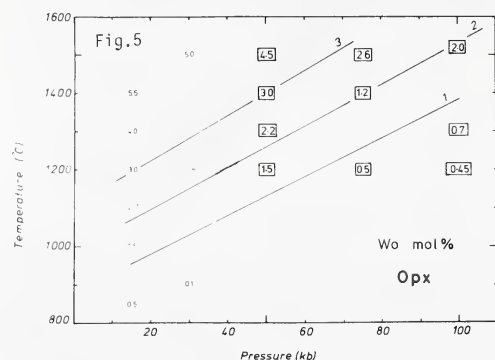


Fig.1



The amount of pyroxene components dissolved in the garnet solid solution becomes greater as pressure increases (about 2 mol % at 50 kbar, 9 mol % at 75 kbar and 20 mol % at 100 kbar). The ratio of grossular to pyrope molecules in the garnet solid solution decreases as temperature increases. The net amount of pyroxene components dissolved in the garnet solid solution, however, seems to be relatively insensitive to temperature at a given pressure. The composition of garnet obtained at 75 kbar and 1200°C in the CMAS system is slightly enriched in grossular component than that of a natural garnet lherzolite run at the same P/T condition by Akaogi & Akimoto (1979).

Alumina contents of ortho- and clinopyroxenes coexisting with garnet are shown in Fig.3 and Fig.4, respectively. Alumina isoplethal lines for the pyroxenes were drawn in accordance with the reversed experimental results of Parkins & Newton (1981) at 20 to 40 kbar and 900° to 1100°C. The dT/dP slope and the



location of the isoplethal lines for orthopyroxene are in harmony with the estimation by Parkins & Newton but are not consistent with those of Akella (1976). The dT/dP slope of the isoplethal lines for clinopyroxene estimated by Parkins & Newton (broken lines in Fig.4), however, are appeared to be overestimated. In consequence of the gentle dT/dP slope of the isoplethal lines for clinopyroxene, the alumina content of clinopyroxene coexisting with orthopyroxene and garnet in the CMAS system is greater than that of orthopyroxene at pressures above about 50 kbar, whereas it is less aluminous than the latter at 30 kbar (Boyd, 1970).

The pressure/temperature dependence of the Wo mol% (defined as $100\text{Ca}/(\text{Ca}+\text{Mg}+0.5\text{Al})$ in the CMAS system) of the coexisting ortho- and clinopyroxenes are shown in Fig.5 and Fig.6, respectively. Because pyroxenes in the present study contains very small amount of Al_2O_3 (Fig.2), the Wo mol % of the pyroxenes in the CMAS system should not be different appreciably from those in the Al-free system. The present results, therefore, are compared with the reversed experimental data in the diopside-enstatite system by Mori & Green (1975) and Lindsley & Dixon (1976) in the pressure range 15 to 30 kbar. The pressure effect on the pyroxene solvus (Mori & Green, 1975) is confirmed to be present at least up to 100 kbar in the light of the present results (Fig.5, Fig.6), and it follows that the equilibrium temperature estimation from the pyroxene solvus cannot be made without knowing the pressure of equilibration.

Given above observations, sheared garnet lherzolite xenoliths from Lesotho kimberlites (Nixon & Boyd, 1973) are considered to have derived from the pressure range 50 to 70 kbar, whereas the granular garnet lherzolites from the same area may have originated at pressures below 50 kbar. The inferred pressures for the sheared lherzolite xenoliths are higher than the estimations by the previous authors (e.g. Boyd, 1973; Parkins & Newton, 1980).

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H12 CHEMICAL AND ISOTOPIC CHARACTERISATION OF UPPER MANTLE METASOMATISM IN PERIDOTITE NODULES FROM THE BULTFOONTEIN KIMBERLITE

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Further major, trace element and Sr-isotope measurements, together with new REE and Nd-isotope measurements, have been made on samples from a much larger peridotite suite than that studied previously [1,2]. For present purposes the suite has been divided into garnet peridotites (GP) which contain no texturally equilibrated or "primary" phlogopite, garnet phlogopite peridotites (GPP), phlogopite peridotites (PP) and phlogopite K-rich peridotites (PKP). The latter two groups contain no garnet, while diopside may or may not be present in all four groups. The above sequence was previously considered [1] to represent one of progressive mantle metasomatism, culminating in the devel-

opment of K-rich peridotite. However, in view of the greatly increased number of PP rocks now obtained, which appear to have been essentially harzburgitic in original composition, it is questionable whether garnet removal was involved or is essential in the development of the PP and PKP groups. Most samples studied are coarse grained peridotites, with deformed textures being much more common in the GP and GPP groups. However three PKP samples have deformed textures in which both phlogopite and K-rich peridotite have been involved in the deformation process, indicating that these minerals formed before kimberlite emplacement. Additional PKP samples include many more veined examples in which the